Atomic collision dynamics in optical lattices

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Optical lattices are created by a set of interfering laser beams [1]. The periodic polarization gradient of the combined fields creates a periodic optical potential structure due to the interaction between the field and the atoms. Atoms may then localize into the wells of the potentials provided that the kinetic energy of the atoms has been reduced enough via laser cooling.

On the other hand the laser cooled atoms may gain kinetic energy in the presence of near resonant light through cold collisions between atoms [2]. This is due to the fact that the duration of the collision becomes long compared to the excited state lifetime of the quasimolecule at the laser cooling temperatures ($T \leq 1K$). Previous studies of cold collisions between atoms trapped into magneto-optical traps show heating of the atomic cloud and loss of the atoms from the trap due to collisions [2].

Here we have studied the effect of atom–atom interactions on the dynamics of the atomic motion and localization in near resonant red detuned $1D$ optical lattices. When the occupation density of the lattice sites increases binary interactions can not be neglected and collisions affect the steady state properties of the atoms in the lattice.

We have used Monte Carlo Wave Packet (MCWP) method [3] to perform calculations for $J_g = 1/2$ and $J_e = 3/2$ atoms in an optical lattice. We take into account the position dependent coupling of the atoms to the laser field and the resonant dipole–dipole interaction between the atoms (keeping one atom of the colliding pair fixed in position) by using atomic basis. In other words we solve the time evolution of a 36 level quantum system including two different position dependent couplings, and dissipation of energy due to quantum jumps. The excited atomic states have not been adiabatically eliminated due to their key role in the energy changing cold collisions. This is a very challenging numerical task and requires operating near the limits of currently available computer resources.

Results (Fig. 1) show how the steady state kinetic energy changes as a function of the occupation density of the lattice for one set of laser parameters ($U_0 = 583E_r$) [4]. In addition of heating there is loss of atoms from the lattice due to collisions. We give estimates for the atomic loss fraction as a function of the density of the lattice based on different values of the critical velocity. This velocity does not have a single value for MCWP histories due to the stochastic nature of the jumps and branching of the wave packets.

Studies of cold collisions in optical lattices is an extension for previous collision studies

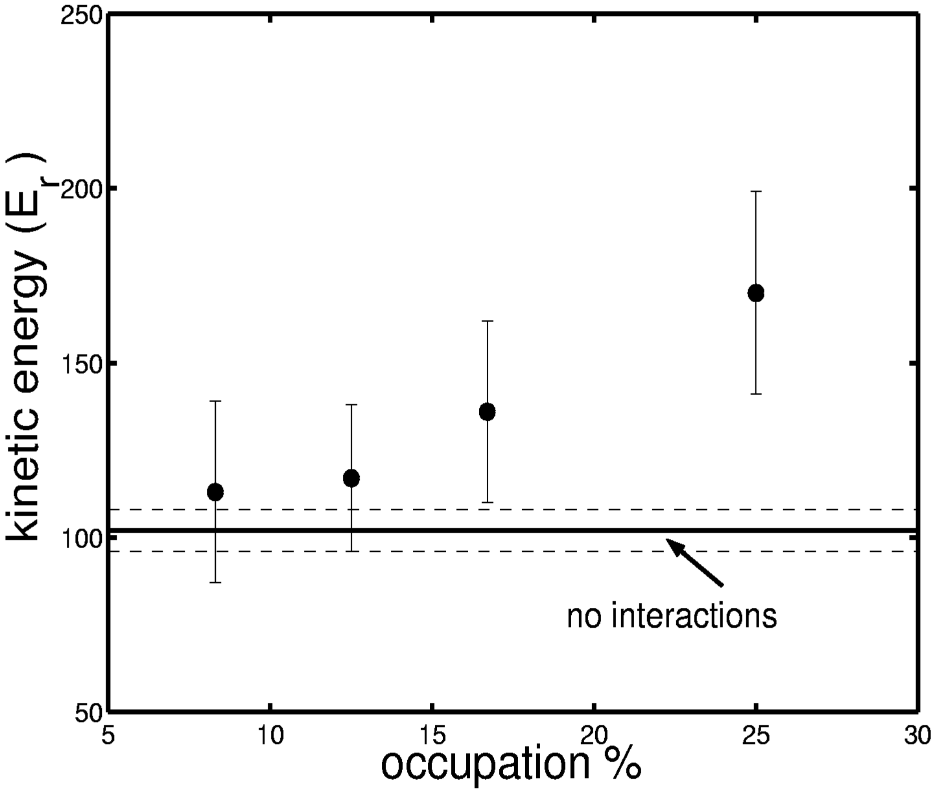

Figure 1: Steady state kinetic energy of the atoms in the lattice as function of occupation density.

dealing with atoms trapped into magneto-optical traps [2]. Since the MCWP simulations are numerically demanding there is an obvious need to develop semiclassical models. Results from the current MCWP calculations can then be used e. g. as benchmarks for these semiclassical models.

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